

**FINAL TECHNICAL REPORT**

**Nebraska Photovoltaic System Case Study**  
**Water Pumping Application**

Prepared for



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## Introduction and Executive Summary

The Iowa Department of Natural Resources (DNR) awarded a contract to Black & Veatch to develop technical case studies for four photovoltaic (PV) applications installed since 1999 in six Midwestern states - Iowa, Illinois, Minnesota, Wisconsin, Missouri and Nebraska. The purpose of these case studies is to independently demonstrate and verify the reliability and viability of photovoltaic systems.

Efforts were made to choose case studies that were diverse in applications and geographic locations. Black & Veatch prepared a questionnaire (Appendix A) and contacted various manufacturers, installers and owners of photovoltaic systems. The key aspect in choosing applications for the various case studies was availability of elaborate project information and production data. The following case studies were selected from a variety of applications:

- Crandon, Pulaski and Oshkosh-West Public Schools - Wisconsin
- Sac and Fox Indian Settlement Pond Circulator - Iowa
- Ciernia Home - Minnesota
- Kreitman Ranch Water Pumping - Nebraska

This document presents the Kreitman Ranch Water Pumping case study. The Kreitman ranch owner wanted to ensure uniform cattle grazing activity across all areas of the ranch. The ranch owner successfully developed a solar water pumping system to deliver water to the under-utilized pastures. Grundfos, a manufacturer of solar water pumps designed and installed the system at the ranch. The total design, procurement and installation period was about six months. The system pumps water at about 25 gallons/min ( $1.57 \times 10^{-3} \text{ m}^3/\text{s}$ ). Including well drilling, the total installation cost was \$5,510. The system installation has resulted in significant cost savings and emission reductions and has demonstrated the applicability and suitability of solar PV technology for remote locations.

Black & Veatch collected information on project timeline and history, design, procurement and installation process, operation and maintenance costs, production data and conducted an analysis on energy and emission savings. The results are presented in the next section.

## Kreitman Ranch Water Pumping – Nebraska Case Study

### ***Project History***

In April 2001, the Kreitman ranch in Bassett, Nebraska maintained about 45 cow/calf pairs. Natural running water was only available on a few areas of the ranch, causing grazing pressure to be intense on those acres. The ranch owners wanted to encourage cattle grazing in other portions of the ranch to prevent damage to the natural water sources. As a solution, the Mike Kreitman, owner of the ranch, decided to drill a well in an under-used pasture and pump water for the cattle.

The ranch selected a well site that allowed use of an under-grazed section of land. Because grid power is not available near the well location, using electricity to run the well was not an option. The Kreitman ranch considered a wind turbine to run the water pumps, but a solar system was estimated to provide more consistent water production. The ranch then consulted Grundfos, a pump manufacturer, to select a pumping system powered by solar photovoltaic modules. Grundfos was interested in using the Kreitman ranch as a field test site for this new technology. The solar pumping system made it possible to supply water to the desired location and promised virtually no maintenance.

Since utility interconnections or power lines were not needed in the installation, no utility negotiations were necessary. Zoning, permitting and inspections were not required because of the remote location of the well and agricultural use of the land. The only preparation work for the solar pumping system involved drilling the well itself. The ranch owner had prior experience as a well driller and pump installer with Grundfos. The owner's prior positive experience using standard Grundfos well pumps was a key factor in selecting the system.

### ***Design and Procurement Process***

As the first step in sizing the system, Grundfos selected North Platte, Nebraska as the closest location to the well site for which solar radiation data was available. Solar radiation information from the National Renewable Energy Laboratory shows the average amount of energy from the sun that strikes an area on each hour of the day. Grundfos used the North Platte location to determine the appropriate equipment for the pumping system and to calculate the electricity that could be generated by photovoltaic panels at the well site.

Grundfos then defined site-specific conditions and requirements of the applications. The company determined the amount of water to be pumped for grazing to be about 5,000 gallons/day ( $2.2 \times 10^{-4} \text{ m}^3/\text{s}$ ). They estimated the depth of the water level below ground and

the height difference between ground and the water-storage tank/reservoir outlet. Grundfos used these values to determine height and diameter of the pipe through which water would be pumped. Based on the selected pipe height, diameter and above variables, they calculated the total friction losses and total head required by the pump.

Once the site parameters were defined, Grundfos had to establish additional parameters such as the month for which the system was to be sized and selection of either fixed or tracking solar panels. In consultation with the ranch, they selected July as the optimal month upon which to base the system size. This was to ensure that the maximum flow rate would be available during the “peak month” of July, when grazing pressure would be most intense. The output from the solar pumping system would vary by month as the hours in the day change, and the angle at which the sun strikes the earth varies. Grundfos could have selected a tracking photovoltaic system that followed the sun’s movement and thus provided a more consistent flow rate. However, the company determined that a tracking system was not necessary and would have added to the total cost of the system. As a result, Grundfos selected a fixed solar system

Based on the needs of the application and cost factors, Grundfos chose their 25-SQF-3 pump and the GF-43 solar panel. Grundfos did not consider any battery back-up as it was not required for this application. Design details on the GF-43 panel and the Grundfos 25-SQF-3 pump are provided below.

The 25-SQF-3 is a 3-stage helical rotor pump with a rated flow of 25 gallons/min ( $1.57 \times 10^{-3}$  m<sup>3</sup>/s) that is appropriate for high-head applications requiring low flow such as ground water pumping. The material of construction is 304 stainless steel. The complete system includes the submersible pump and switchbox. The Grundfos GF 43 solar panel consists of eight modules, each capable of generating 43 Watts (146.8 BTU/hr) for a total of 344 Watts (1174 BTU/hr). The module is made of amorphous silicon, thin-film type designed specifically for use with the SQF systems and comes equipped with plugs and sockets enabling easy and simple installation.

A Grundfos distributor provided the PV panels and the pumping system. The ranch procured other equipment (well casing, submersible cable, piping, and concrete) from a local hardware store.

### ***Installation Process***

In April 2001, Grundfos added Kreitman ranch to the list of potential field test sites. In June 2001, the ranch drilled the well after design and sizing was completed.

Grundfos shipped the system directly to the ranch in late August 2001. The ranch purchased all additional materials, such as pipe and wiring. The pump installation followed the procedure for installing a typical conventional submersible pump. The solar panels came with support structures, wiring kits and the controller.

On September 8, 2001, ranch personnel constructed and checked the system support structures. They dug and poured the concrete footings to provide a stable platform for the solar panels. The next day, they anchored the structures to the footings and installed the panels onto the structure. They then made the connections and started the pump, assembling the system in about 12 hours.



The installation required no major hardware components other than basic materials available from a hardware store. The ranch owner is a qualified installer of these products and has performed six installations, not including his own field test installation. However, at the time of installation, no training on this particular system had taken place and the ranch owner installed the

system using only the provided documentation. The ranch owner had no suggestions concerning improvements to the documentation or the system components.

### ***Timeline***

Mike Kreitman, the ranch owner initiated the project in April 2001 when a Grundfos distributor informed him of field testing for a new renewable energy pumping system. At that time, Mr. Kreitman concluded that he could get better use out of his available pasture by installing a well and pump in an under-used portion of land. He then volunteered his ranch to be a field-test site and Grundfos subsequently added his ranch to the list of potential sites. In consultation with the ranch, a Grundfos product manager determined the application requirements regarding depth to water, desired flow, and location, in order to size the system. As the system was not yet in full production, the ranch had a waiting period to receive the pump and solar system. The ranch received the pumping system on approximately August 25, 2001. They started the installation on September 8, 2001 and completed it on September 9, 2001.

**Table 1: Nebraska - Installation Timeline**

Event	Date
Initial meeting with system provider	April 2001
Design, sizing and system order complete	June 2001
System delivered on site	August 25, 2001
Installation period	September 8-9, 2001

**Production Data**

Production data for PV applications like this water pumping application is not typically measured directly in terms of the electricity produced by the PV cells. The production data is usually expressed in terms of the monitored variables, which in this case was the flow rate of pumped water. The ranch owner developed the data listed in Table 2.



This system was a field test for new equipment; therefore, Grundfos initially installed a flow meter to record accurate production data. Upon initial startup, at approximately 3:00 p.m. on Sunday, September 9, 2001, the system pumped water at a rate of 23 gallons per minute ( $1.44 \times 10^{-3} \text{ m}^3/\text{s}$ ). Over the first week, the ranch recorded readings from the flow meter daily. The flow rates were as follows:

**Table 2: Nebraska – First Week Production Data**

Measured Production Data in First Week of Operation	
Day and Time	Production (gal/min)
Monday 9:00 a.m.	14
Tuesday 3:00 p.m.	21
Wednesday 3:00 p.m.	23
Thursday 4:00 p.m.	20
Friday 3:00 p.m.	23
Saturday 12:00 p.m.	27

Over the first 10 days of operation, the system pumped 73,700 gallons of water ( $278.6 \text{ m}^3$ ). Shortly after that, the ranch moved cattle into the pasture, so exact measurements were no longer possible. Additionally, upon an initial hard-freeze, the dials on the flow meter froze

and broke off. The ranch did not replace the meter; however, the ranch estimated an average production per day by month for the next year from the water level in the tank. The estimates are as follows:

**Table 3: Nebraska – Estimated Monthly Production Data**

<b>Month</b>	<b>Production (gal/day)</b>
September 2001	7,000
October 2001	6,000
November 2001	5,000
December 2001	4,000
January 2002	4,000
February 2002	5,000
March 2002	6,000
April 2002	6,000
May 2002	7,000
June 2002	6,000
July 2002	7,000
August 2002	7,000

***Financial Incentives***

The major motivation for installation of a water pumping system was to open an under-grazed portion of the ranch’s land to cattle. This has enabled the ranch owner to reap two benefits: he is able to raise more cattle on the same size ranch, increasing ranch income; and other areas of the ranch are not grazed as intensively, which allows for a quicker recovery time in those areas. The solar powered pumping system was the most economical way of providing these benefits to the ranch owner. There were no property or tax ramifications for the ranch owner.

Nebraska offers few tax incentives for renewable energy systems. However, the cattle operation is organized as a business, so it is eligible for the Federal Business Investment Tax Credit for Qualifying Energy Property. This credit allowed the Kreitman ranch to claim up to a 10 percent credit on installed qualifying solar renewable energy equipment, which included the solar panels. The tax credit is available for commercial and industrial businesses that invest in solar and geothermal energy property and has a limit of \$25,000 per year.

***Project Cost***

The ranch owner drilled the well at an approximate cost of \$500. The non-system equipment for this project included well casing, submersible cable, piping, and concrete; the total estimated cost was \$400. The solar pumping system (including the GF43 solar modules, support structures, a Grundfos 25-SQF-3 pump, controls, and miscellaneous wiring) was provided at no cost to the ranch since this was a trial demonstration project to verify system viability. However, the entire system is estimated to cost \$4,610. The total project cost would

have amounted to about \$5,510. This cost is estimated to be significantly lower than the cost to run a traditional power line to the well. Grundfos and the Kreitman ranch did not estimate the cost of a traditional power line as it was not considered technically feasible for this application.

There is no maintenance required or suggested for the pump by the manufacturer. As such, no maintenance has been performed on the pump. Suggested maintenance for the solar panels consists of cleaning the solar modules with clean water, cutting down plants that might shade the modules, and tightening any loose bolts on the support structure, all as necessary depending on environmental conditions. Maintenance so far has been performed by the ranch and has only included hand cleaning of the solar panels as necessary. At an estimate of 20 minutes of labor each time the panels are cleaned, and with a cost of \$25 per hour, the total maintenance bill has been about \$25 thus far. There are no additional costs associated with operating the system.

The system originally included a flow meter to measure output from the pump. During a hard freeze on approximately October 27, 2001, the dials on the flow meter froze and broke off. The meter is not required for effective operation of the system, thus it has not been replaced.

### ***Energy and Emission Savings***

The Grundfos system is a dedicated solar water pumping system. All electrical production from the solar array is used by the pump. The panels produce power that is adequate for power usage and no “excess” electricity produced. The pump control box consists of a simple on/off switch, and requires no power for the pump controller. The pump motor handles the DC-to-AC power conversion and pump condition monitoring.

The Grundfos PV pump system was sized to pump 5,000 gallons/day of water at a head of 10 meters (33 feet). The installed GF-43 solar panels had a capacity of 344 Watts. Solar panel ratings indicated that the annual energy production would be approximately 700 kWh. Table 4 shows the estimated emission and energy savings from the Grundfos installation based on the following assumptions:

- According to U.S. Environmental Protection Agency (EPA), a 1 kW solar PV system installed in Nebraska results in annual emissions savings of 4,570 pounds (2,077 kg) of carbon dioxide, 7 pounds (3.18 kg) of nitrogen oxides, and 9 pounds (4.09 kg) of sulfur dioxide.
- The average cost of electricity for the Kreitman ranch is 6 cents/kWh.

**Table 4: Nebraska – Energy and Emission Savings with a Capacity of 344 Watts**

<b>Annual Generation (kWh)</b>	<b>Energy Savings (\$)</b>	<b>Sulfur Dioxide Offset (lbs)</b>	<b>Nitrogen oxides Offset (lbs)</b>	<b>Carbon Dioxide Offset (lbs)</b>
700	42	3.1	2.41	1,572.1

Table 4 does not include the savings from the avoided cost of running a grid connected transmission line to the pump as Grundfos; the ranch owner believed that the transmission line was not a technically feasible option for this application and thus they did not estimate the cost.

***Lessons Learned***

The following lessons were learned from system installation:

- Use of the solar pump system in relatively barren areas reduces grazing on land that is reliant on naturally running water sources. This, in turn, reduces the negative environmental impact on those water sources, such as bank erosion and nitrogenous waste in the water.
- Use of the solar PV system is effective in transporting water to remote locations in a ranch to meet grazing needs.
- Installing, operating, or maintaining the solar PV system does not result in negative environmental impacts.
- With basic knowledge of well drilling, it is possible to install the solar PV system without high labor costs.

## Appendix A: PV Questionnaire

We are pleased to inform you that Black & Veatch has been selected by Iowa Department of Natural Resources to conduct a case study of solar PV applications installed since 1999 in the Midwest. Please provide the following information as part of the study. We thank you for your cooperation. This report will be distributed widely to engineers, at technical workshops and published over the Internet to promote solar PV systems.

### Project History

- Project Name, Size and type of PV cell, and Owner or final end user with contact information.
- Reason for choice of photovoltaic system as energy source.
- Negotiations conducted with regulatory authorities and utilities.
- Permitting, zoning and all other applications that were filed.
- Other activities preceding project construction.

### Design and Procurement Process

- Selection of type of photovoltaic system among various alternatives.
- System (PV and inverter) sizing procedure, one-line electrical wiring diagram and instrumentation details.
- Who was responsible for sizing the system?
- Procurement process and system delivery time-table including major milestones.

### Installation Process

- Installation schedule.
- Capital costs.
- Major hardware components including any tracking system used for installation.
- Ease of finding qualified contractors to do the installation.
- Could the end-user have assembled (direction, azimuth, elevation, wiring, mechanical assembly, etc?) the system by themselves with adequate instructions?
- Lessons learned during construction that can be applied to future projects.

### Timeline

- Process time-line from initial vision, system engineering, procurement, installation and start-up.

### Operations Costs

- Annual cost of operating and maintaining the system.
- System reliability and major problems faced with operation and maintenance.
- How many times was routine maintenance required annually and is routine maintenance possible by the owner themselves?

### Production Data

- Please provide electric production (or water pumping) data or performance summary for any consecutive 12-month period since 1999 to verify system reliability.

### Electrical Consumption

- What is the ratio of electricity consumption for the load served by the photovoltaic system against the total electricity produced by the system?
- Applications for which PV-produced electricity was used.

### Financial Incentives / Energy and Cost Savings / Economic Analysis

- Financial incentives considered while undertaking project development and other activities preceding project construction.
- Summary of annual energy, monetary and emission savings.
- Tax ramifications/benefits.

### Environmental Issues

Environmental issues surrounding operation and maintenance of the photovoltaic system.